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ROCKET POSTS

By L. J. Carter, F.R.S.A., A.C.I.S.

It is the practice nowadays for all important events to be marked by the issue of commemorative stamps, and although we have yet to see the first to feature space-flight, several stamps have appeared depicting rockets.

The first of many, but unofficial, rocket stamps appeared as far back as in 1931, and these were continued from various sources over a number of years. All were printed for and sold by the actual rocket experimenters themselves, in an effort to obtain the much-needed funds for their experiments. The rockets were made to carry mail in the first instance in an endeavour to interest some large public body which might later be induced to provide the funds for further experiments.

The first successful postal rocket shot was that by Ing. Fredrich Schmiedl on 2nd February, 1931, his powder rocket carrying 102 pieces of mail from Schoeckel to Radegund (in Austria). Even prior to this, in 1928, Schmiedl had been endeavouring to obtain support for a stratosphere balloon project, for which again special stamps were to be issued. Schmiedl's Austrian experiments were carried on for some years, but were brought to a close in the spring of 1935, reputedly as a result of political pressure. However, a number of successful shots had been made during this time, some, notably the "R1", with Post Office co-operation. In December, 1933, he initiated a two-step rocket, both steps containing separate fuel and postal compartments. The first step propelled the whole for part of the way, and then floated to earth with its payload of letters, while the second step continued on its way. Although these Austrian experiments had been brought to a premature end, Weihs, his associate, made three successful shots just over the border in Yugoslavia, later in 1935. In all these early experiments solid fuels were used, but there is a possibility that the Yugoslav experiments involved the use of a liquid fuel.

About this time rocket experiments were taking place in many other countries. The first of the German postal rockets was fired by Reinhold Tiling in April, 1931, his rocket looking something like a long, thin pencil, for though it was about 12 feet long, it was only about 8 inches in diameter. Gerhard Zucker also despatched several mail rockets near Hamburg in 1933. His rocket was displayed at the International Air Post Exhibition, held in London in 1934, and subsequently several experiments took place in England. These were all ill-fated. The first attempt, on the Sussex Downs, near Rottingdean, did not come up to expectations; the second, between the islands of

Typical Postcards carried by Rocket Mail.

Official Cuban Rocket Experiments, 15th October, 1939

German Rocket Battery in Action. (Second war issue, 1943)

Large Rocket being launched, Fort Bliss. Centennial issue (U.S.A.) 1948

Scarp and Harris in the Hebrides, came to a premature end by the rocket exploding, while the third attempt, from Lymington to the Isle of Wight, was frustrated by a high wind, which forced the rocket back along the mainland beach.

In America, too, a number of such experiments took place. The late Professor Goddard undertook two mail firings in July, 1936, these being made between Texas and Mexico, over the Rio Grande.

The most prolific of all the postal rocket tests were those made in India by Stephen H. Smith. They began in September, 1934, and continued for about seven years. Frequent firings took place throughout this time in all sorts of circumstances and conditions, the rockets being sometimes used to carry food and Red Cross equipment, as well as mails.

Other attempts too, but on a very much reduced scale, were also made in Italy, Switzerland, Holland, and Australia.

The private stamps used on these early pioneer rocket mails varied enormously in design, format and application. Some were not even of the adhesive type, the franking being identified by special "cachets" (i.e. rubber stamp markings), while adhesive labels instead of perforated stamps were used on others. The majority of all mails bore, in addition to the rocket postmarks, the ordinary postage stamps of the country concerned, to prepay normal postal transit after the firing.

So far only one rocket post stamp has been issued officially by a postal authority, this being the 10c. air stamp of Cuba, specially overprinted "*Rocket Post Experiment,*" for use on mails fired in Cuba on 15th October, 1939. Little is known about the actual experiment, but it is believed to have been unsuccessful.

Only two other official stamps have been issued which are of interest to rocket enthusiasts, but neither is associated with any rocket mail experiment. The first, issued by Germany during the recent war, shows a rocket battery in action, while the second, recently issued by the United States, shows the launching of a large rocket.

America has also been to the fore in the astronomical field, and a recent stamp shows the new Mount Palomar Observatory.

Perhaps the Transatlantic rocket mail stamps so frequently forecast before the war may never appear, as fewer stamps are issued nowadays to denote any specialised form of transit, and it may therefore be doubtful if a special stamp would be issued for mail to be carried by any type of rocket plane rather than an ordinary aircraft, but who knows how soon it will be before keen philatelists commence to accumulate specialised collections of stamps issued by the various space stations, lunar colonies, and other outposts of civilisation!

THE RESEARCH SCENE—1

By Kenneth W. Gatland

Introduction

The intention in this series is to present information, from all sources, on the development of guided missiles and associated equipment. Particular emphasis will naturally be given to *long-range* and *high-altitude* rockets, but it is hoped, in addition, to feature reviews of design studies which from time to time appear in the journals of contemporary societies and research groups.*

Photographs from A-4 and Aerobee

The possible value of the high-altitude rocket as a tool of military reconnaissance is shown in a new series of photographs released by the United States Navy Department. A composite picture† made up of seven separate plates, obtained from an A–4 at a height of approximately 60 miles (96·5 km.), extends a distance of 2,700 miles (4,344 km.). The rocket, which was fired from White Sands, New Mexico, provides a view of an area stretching from Mexico in the extreme south to the Sangre de Cristo Range in the north. Other identifiable surface features are the Gulf of California, the Magadalena Mountains and the Rio Grande River.

Similar photographs taken at an altitude of 70 miles (112 km.) from *Aerobee* show even more remarkable detail—Biggs Field Army Air Base; the Southern Pacific Railway, with adjacent highway; A–4 and *Aerobee* launching sites and Base Headquarters, White Sands; and the site of the first atomic bomb test. The distance measured across the horizon is 1,400 miles (2,253 km.).

A single camera was installed in the A–4 and two in the *Aerobee*, one in the latter using colour film. All three were modified K.25 aircraft cameras, designed by the Fairchild Camera and Instrument Corporation, and manufactured by the Graflex Corporation: lenses—Ilex Paragon anastigmat, f.4·5-163.

The project was conducted under contract with the Navy Bureau of Ordnance by the Applied Physics Laboratory, Johns Hopkins University.

* The author will be pleased to receive information on any relevant subject for review, which should be addressed to him at 17, Southcote Avenue, Tolworth, Surbiton, Surrey, England.

† See page 145.

Picture of the Earth's surface from an "Aerobee" rocket at 57 miles altitude.

The Earth Satellite Vehicle

The early objectives of the Earth Satellite Vehicle Programme (revealed by the late Mr. James V. Forrestal, the former Secretary of Defence, during the First Annual Report to Congress on the National Military Establishment, on 29th December, 1948) is allegedly to determine by remote observation happenings in foreign states affecting security, such as the test of atomic weapons. While speculation on more sinister applications for satellite rockets is current, with particular emphasis on the sub-orbit as an atomic bombing platform, the significance which this research may have in various branches of pure and applied science is considerable, and is probably the initial reason for the U.S. interest. Some of the more important possibilities in the ultimate development may be summarized as follows:—

(*a*) A meteorological station of unique coverage.

(*b*) An astronomical observatory with greatly improved visibility.

(*c*) A radar beacon for effective position finding on 24-hour period orbit.

(*d*) A relay station to receive television beamed to it and diffuse the programme over nearly an entire hemisphere of the globe. Three stations situated 120 degrees apart would serve the entire planet—such a development would be applicable to any short-wave radio transmission, and would also have military uses in connexion with missile guidance.

(*e*) A "hard" vacuum research laboratory, especially suited to the study of electronics.

(*f*) An extreme temperature laboratory of range extending from "absolute zero" to a temperature of several thousand degrees Fahrenheit.

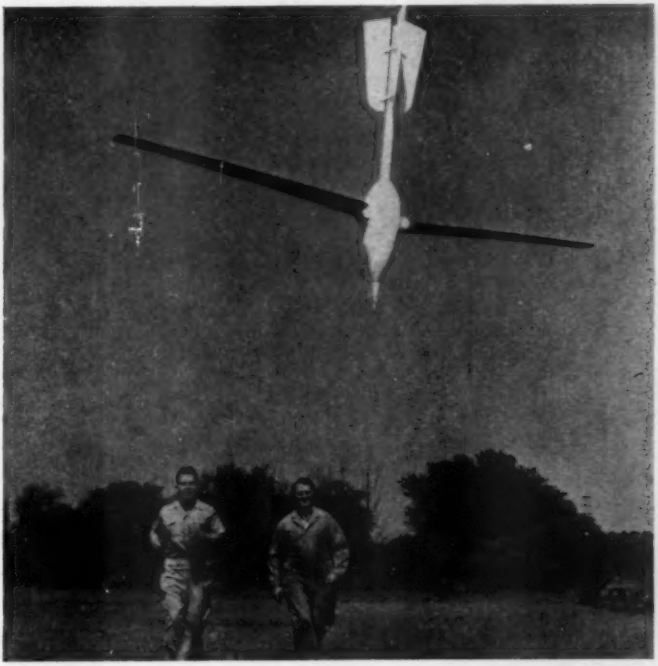
(*g*) A chemical research laboratory for testing the behaviour of common chemical reactions in a vacuum in the absence of effective gravity.

(*h*) A biological laboratory for the observation of cell growth and division in the presence of corpuscular and electromagnetic radiations and without the benefit of gravity.

(*j*) An orbital "Escape" rocket, utilizing secondary rockets for re-fuelling in the sub-orbit to obtain "escape velocity."

The project is, of course, still in an early formulative stage, but the Report revealed that investigation into the design of close-orbit satellite rockets had been in progress two years and contained this statement: "The Earth Satellite Vehicle Programme which is being carried out independently by each military Service, was assigned to the Committee on Guided Missiles for co-ordination. To provide an integrated programme, the Committee recommended that current efforts be limited to studies and component designs; well defined areas of such research have been allocated to each of the three military departments."

The first objective of the Programme will clearly be a guided missile to reach orbital velocity close to the Earth at, say, 500 miles (804 km.) altitude—probably a three-step rocket with a payload of instruments.



The Rotochute.

The Rotochute

A new type "high-speed" parachute, intended for use in retrieving recording equipment from high-altitude rockets, was tested recently by engineers of the General Electric Company. In effect, the device is a large hollow-nosed dart with two rotor blades which fold outwards from near the tip. The final version (a test model is illustrated) will house from 20 to 30 lb. (9 to 13·5 kg.) of instruments.

A year of intensive research in which twenty-three different types of rotary-wing brake were tested went into the development. Wind-tunnel tests of the various models were made to simulate flight speeds up to 1,300 m.p.h. (581 metres/sec.), together with actual dropping trials from a B.29 flying at 35,000 feet (10,675 metres). Other drops were made from light aircraft and later from rockets.

Ordinary parachutes were ripped to shreds after falling free into the denser atmosphere, according to G.E. engineer and test pilot, Mr. I. B. Bensen, designer of the accepted model. Expelled from A–4 rockets at altitudes up to 100 miles (161 km.), the rotochute attains supersonic velocity before atmospheric density

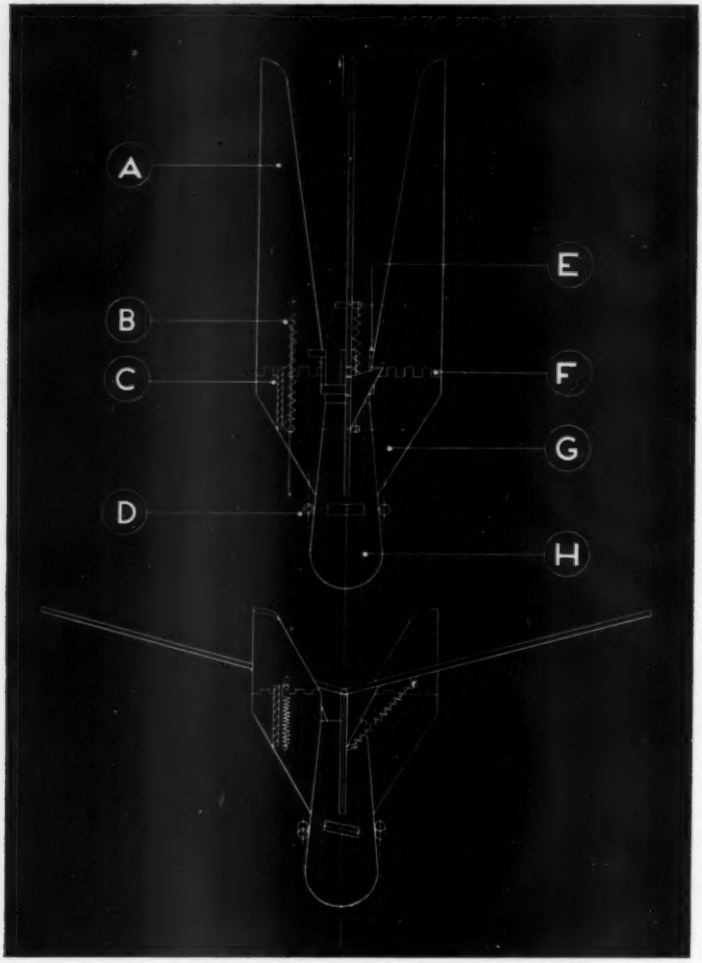


Diagram of the Tiling "Flying Rocket."
(U.S. Patent 1,880,586 Tiling, Osnabruck, Germany, 1932)

Key to Diagram:—A. Fins (in extended position). B. Springs. C. Incidence piece. D. Powder charges. E. Locking plates. F. Hinges. G. Fixed Fins. H. Payload compartment.

builds up and the blades begin to revolve, gradually being forced out against air pressure to assume a horizontal position. The braking action is such that the final speed on landing is less than 30 m.p.h. (13·5 metres/sec.). The model is approximately 4 feet (1·2 metres) long, with a maximum body diameter of 8 inches (20 centimetres). Fully extended, the rotor blades span 8 feet (2·4 metres).

General Electric are also reported to be considering "Rotochute Technique" as a means of emergency escape from supersonic aircraft and for supplies dropping.

Reminiscent of Tiling

The Bensen rotochute recalls a design patented by the late Reinhold Tiling (U.S. Patent 1,880,586) in 1932. The Tiling "Flying Rocket," as the device was termed, was a finned rocket with a solid fuel charge fitted into the body, with space for payload in the nose. There were four fins extending back from the rear, but the unique part of the design was that these were hinged and, after firing had ceased, they collapsed at a set angle of incidence, to form supporting planes. This was arranged by a time-fuse which detonated a small charge and ejected the spent propellant cartridge from the rear at the calculated peak trajectory. The four locking plates, adjacent to the fins, were deflected by this action, transforming the rocket into a device which spun to the ground. It was also suggested that four small rocket charges firing tangentially from the body would produce increased "lift" to reduce the rate of fall just prior to landing.

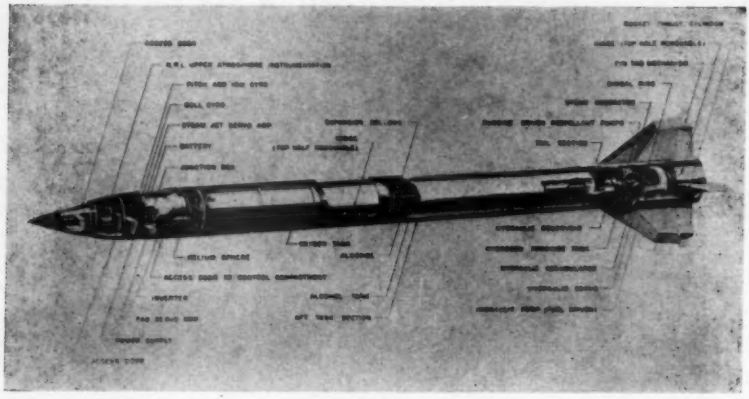
First Steps into Space

The successful combination of A–4 and *WAC–Corporal* as a step-rocket and the record altitude of 250 miles (402 km.) achieved by the *WAC* after releasing at an altitude of 20 miles (32 km.) (the climax of A–4's powered ascent) are indicative of the line of development which will lead to the satellite vehicle. A velocity of 5,000 m.p.h. (2,235 metres/sec.) was achieved by the final step.

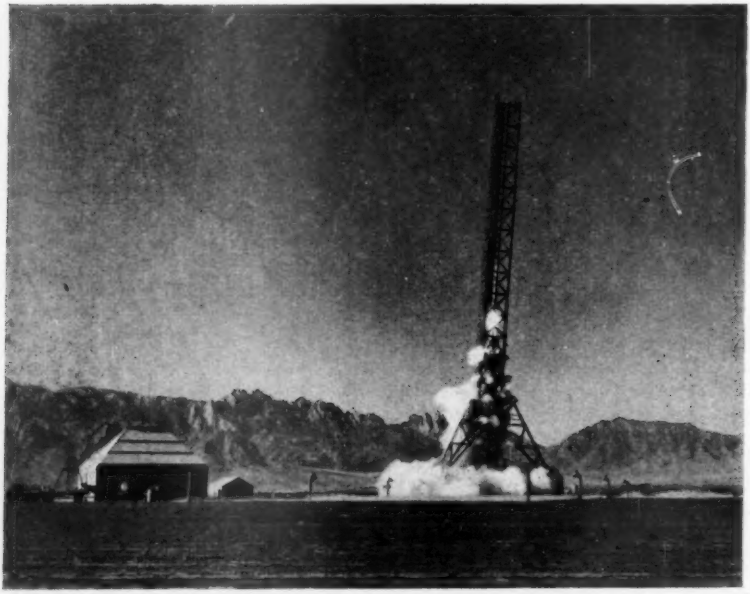
The test which occurred on 24th February, 1949, comes very close to a trip into space, and a great deal should now be learnt of ultra-violet and cosmic radiations before they suffer absorption, scattering, or other secondary effects due to the atmosphere. The experiment was sponsored by the United States Army Ordnance Department, in collaboration with the California Institute of Technology, Pasadena.

Viking

After several months' delay the first firing of the Glenn Martin *Viking* rocket (formerly *Neptune*) has now taken place. The altitude attained was 51½ miles (82·8 km.), but this is no indication of the maximum performance with minimum payload, which is expected to be better than 200 miles (322 km.). Details of the design and estimated performance were given in the *Journal*, December, 1947, pp. 208–9. The rocket is being used by the United States Navy for cosmic ray and atmosphere composition research.



Diagrammatic view of the Viking (formerly Neptune) rocket. This rocket is about the same length as a V.2, but only one-third the weight.



An Aerobee taking off from its launching rack. A solid-fuel propellant is used to start the rocket, and then a liquid fuel takes over for the actual flight.

A REVIEW OF PROGRESS IN ASTRONAUTICS SINCE THE WAR

On March 12, a meeting of the Society at St. Martin's School heard a lecture on the above subject by our present Chairman of Council, which was subsequently followed by a lively and interesting discussion.

Mr. Cleaver began by contrasting the present willingness of the public to accept the possibility of space-flight with pre-war scepticism on the question. Before the war, a few great pioneers, such as Oberth and Goddard, had laid the theoretical foundations of the subject, and the same men (or small amateur groups collecting around them, such as the German V.f.R.) had also demonstrated experimentally the fundamental principles of the liquid propellant rocket. However, only this minority believed in interplanetary travel as a possibility of the not too remote future—the world at large definitely did not. Until after 1939, no rocket had climbed more than two miles up, or developed a thrust of more than a few hundred pounds.

The last ten years had brought radar, jet-propulsion, the atomic bomb, rocket planes such as the Me.163, and the V.2 projectile, with the result that most people were now prepared to accept the view that anything might be possible to modern applied science. In particular, one family, on seeing some of Chesley Bonestell's excellent drawings of a rocket on the Moon, had at first imagined they were colour photographs recording an actual achievement! There was some danger of a reaction setting in, with people asking "If it is possible, why hasn't it been done?"

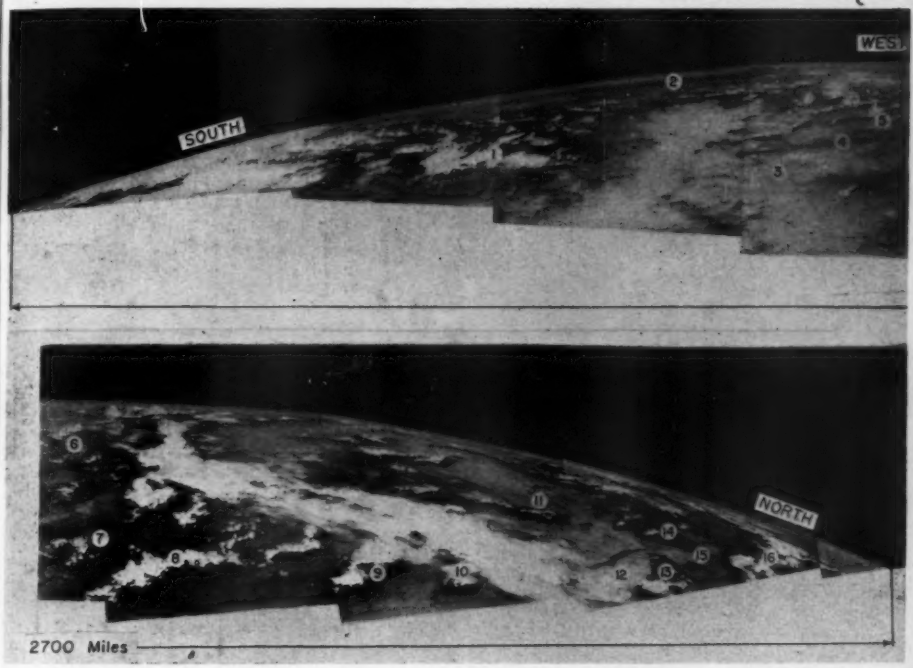
It was part of Mr. Cleaver's purpose to show that real progress was still being made, and that much had been achieved even in the few years since the end of the war. Spaceships would not suddenly be built or "invented"; they would evolve gradually, in part as a result of work originally carried out for quite different objects, some of which might even seem to be irrelevant at the time. All this effort would lead up to the date when the specific problem of interplanetary flight could be attacked; much would then still remain to be done, of course, but a great deal of groundwork would have been covered. The gas-turbine engine offered a parallel; it had been discussed for a generation or more, but was finally realised as the result of gradual progress in air-compressor design and high-temperature metallurgy. The former was largely made in connection with research on superchargers for piston aero-engines (the original competitor of the turbine) and the latter for a variety of purposes, including electric heater elements.

Thus, rocket aeroplanes might seem "off the beam" of true astronautics, but they fostered the design of safe, reliable, rocket motors, and hence made a valuable contribution. So also did any work encouraging research and development on high temperature thermodynamics and heat transfer, on associated material problems, supersonic gas dynamics, or in the whole field of nuclear power. These subjects included most of the ground covered by modern scientific research on aeronautics, guided missiles and atomic physics. Hence, although such current effort was usually sponsored by military or industrial agencies, and certainly not with any interplanetary object directly in view,

First flight of Boeing XB–47 Stratojet Bomber. This 60 ton swept wing bomber is assisted in take-off by 18 Aerojet rockets of 1,000 lb. thrust each.

the fact remained that one day it would all be seen to have contributed to astronautical progress.

Mr. Cleaver then proceeded to illustrate his argument with a number of slides of post-war achievements, starting with one showing a V.2 ascending vertically and quoting the official U.S. Navy report on the New Mexico firings: "Already the V.2 has provided the most important contribution in many



Composite photograph of the Earth's curvature.

This photograph has been made up from a strip of films taken by a V.2 at a height of 60 miles. The distance shown *along the horizon* is about 1,400 miles, from Upper Wyoming to Mexico. The key to the numbered points is as follows:—(1) Mexico; (2) Gulf of California; (3) Lordsburg, New Mexico; (4) Peloncillo Mountains; (5) Gila River; (6) San Carlos Reservoir; (7) Magollon Mountains; (8) Black Range; (9) San Mateo Mountains; (10) Magadalena Mountains; (11) Mount Taylor; (12) Albuquerque, New Mexico; (13) Sandia Mountains; (14) Valle Grande Mountains; (15) Rio Grande River; (16) Sangro de Cristo Range.

years to the fields of solar spectroscopy, cosmic rays and upper atmosphere physics." Also included were pictures of the "WAC Corporal," "Aerobee," and the new U.S.N. "Viking" (formerly "Neptune") rocket, which had not then been fired, but which is expected to ascend to about 240 miles' altitude this year.

Turning to the field of aviation, Mr. Cleaver showed slides of American J.A.T.O. units and aircraft being assisted into the air by them, of the British Vickers trans-sonic model plane, and of American supersonic research aircraft—the Douglas "Skyrocket" and the Bell X-1. The latter, which was wholly rocket-propelled, was the first aircraft in the world to exceed the speed of sound. (The "Skyrocket" uses a jet-engine as well as a rocket.) These, and many other projects for rocket, and rocket plus turbojet, aircraft, were instances

GALCIT test of A–20A assisted by two 1,000 lb. thrust, 25 sec. duration liquid motors.

of post-war progress in aeronautical rocketry. The reason for such interest was the undiminished thrust of the rocket at extreme altitudes, as compared with air-burning types of engine.

There were also many other new types of rocket missile, such as the Convair 774, the Boeing GAPA and the North American NATIV. Most of the projects of this nature on which information had been released were of American origin; this could be attributed to the greater resources of the U.S.A. in money and manpower, the better economic position there, and the existence of a larger American background in liquid-propellant rocketry at the end of the war, as compared with the British. We had done little in this sphere until the end of the War; for the most part, Mr. Cleaver thought this neglect had (so far) been excusable, because such developments would have been (for example) of little use to the British war effort. Now, however, we had to catch up, not only for reasons of vital, even if regrettable, military necessity, but also on grounds of basic scientific research.

The recent pronouncement on "space-stations" by Mr. Forrestal (then U.S. Secretary of Defence) was the first evidence of official interest in projects of a specifically astronautical nature. This American "Earth–Satellite Vehicle Programme" probably amounted to an effort, in the first place, to achieve a relatively small unmanned orbital rocket, capable of telemetering instrument readings back to Earth. The possibilities of larger orbital rockets, or even (at a later date) of true "space-stations," had been well-publicised in the B.I.S. *Journal* and elsewhere. Their use would revolutionise many fields of scientific

research, short-wave radio and television communication, and (as an inevitable by-product of the latter application) the long-range guidance of missiles.

Mr. Cleaver also mentioned the many articles and papers, soberly discussing the possibility of rockets to achieve orbital or escape velocities, which had appeared since the war over the signatures of recognised scientists and engineers, such as Alvarez, Ackeret, Malina and others. Most of these had mentioned the long-term possibility of building an atomic rocket, in which nuclear energy would be used to heat up a secondary working fluid such as hydrogen, to form a propulsive jet. He felt we had to look to such a device to realise eventually the full project of interplanetary flight; the direct use of atomic power, if high thrusts were required, would appear to present insuperable problems in the disposal of waste energy.

Until some agency, somewhere in the world, got down to the specific task of interplanetary rocket research, it was the duty of societies such as the B.I.S. to do three things. Firstly, they should attempt to show how results achieved in other spheres fitted into the astronautical picture. Secondly, they should speculate to the best of their ability on possibilities of a longer-term and more visionary nature than any likely to be receiving the current attention of official research and development establishments. Thirdly, they should strive to stimulate widespread interest and belief in the essential value of the proposal that interplanetary flight should be attempted by mankind.

The B.I.S., with over 500 members, was directing all its efforts in these three directions, and there were now many other societies, in other countries, all with more or less the same objects. In the United States, a considerable number of small societies existed, prominent among which was the Pacific Rocket Society, and also the large American Rocket Society, affiliated to the A.S.M.E. and having over 800 members. In France, the Groupement Astronautique Français, directed by M. Ananoff, was the successor to two earlier bodies, while in Germany societies to follow on the old pre-war V.f.R. had been started in all four Zones of Occupation. All were known as the Gesellschaft für Weltraumforschung, and it was hoped they would eventually amalgamate;

The Bell X-1 (6,000 lb. thrust, Reaction Motors Inc. rocket engine) was the first piloted aircraft in the world to exceed sonic speed in level flight.

The Vickers trans-sonic model rocket plane (here seen slung beneath the Mosquito from which it was air-launched) has an 800 lb. thrust rocket motor designed by the R.A.E., and recently achieved about 900 m.p.h. at 30,000 feet.

Prof. Oberth had recently become their President. There were other societies in Canada, the Argentine and Czechoslovakia, and also plans had been proposed from time to time to start organisations in Australia, Holland and Sweden. In the presence of such world-wide interest, one could feel confidence in the achievement of interplanetary travel before the end of the present century, and it was the hope of the lecturer that he had shown that progress was already being made towards this end.

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NOTE ON SHIELDING OF ATOMIC ROCKETS

By L. R. Shepherd, B.Sc., A.Inst.P.*

The need for shielding the propulsion unit in an atomic rocket has been discussed in Part I of the paper referred to below. It is important in a rocket that the weight of this shielding should be kept to a minimum or the adverse effect upon the mass ratio will offset any improvement in exhaust velocity arising from the use of nuclear energy.

In Part I of "The Atomic Rocket" it was emphasised that the shielding must serve two purposes viz.:—

(*a*) It must protect any "living payload" such as a human crew from the harmful effect of radiation from the propulsion unit.

(*b*) It must prevent the dissipation of excess heat due to absorption of penetrating radiation in uncooled regions of the rocket.

The type of radiation which we shall consider here is hard-gamma radiation since this will be the most difficult to remove and since hard-gamma rays must be emitted from any conceivable nuclear reactor. In order to avoid minimising the difficulties we shall assume that we are dealing with the most difficult region of the gamma ray spectrum, viz.: that between 2 and 5 Mev. A few details of the mechanism of gamma ray absorbtion will illustrate the reason for the low absorbtion in this region.

Gamma rays are absorbed according to an exponential law, *i.e.*:—

$$I = I_o \, exp \, (- \mu x).$$

where I is the emergent intensity of a beam, from an absorber of thickness x (along the beam), with an incident intensity I_o.

The absorption of the rays is brought about by three processes.

1. *The Photoelectric Effect*, in which a gamma photon gives up all its energy in ejecting an electron from an atom of the absorbing material.

2. *The Compton Effect*, in which a gamma photon gives up part of its energy in a collision with an electron. Such a collision is analogous to the elastic collision between two particles, the same rules of conservation of momentum and energy being observed. The photon collides with the electron, gives up some of its energy and momentum to the latter, and bounces off as a softer photon, *i.e.* a photon of lower energy or longer wave-length.

3. *Pair Production*. A gamma photon may disappear with the formation of an electron-positron pair which carries the energy of the photon in the form of rest mass and kinetic energy. This process occurs only for gamma photons having energies in excess of 1·02 Mev and the effect increases with the energy of the photon, in contrast to the first two effects, which fall-off rapidly with increase of photon energy.

Processes 1 and 3 occur only in the vicinity of the nucleus, since the simultaneous conservation of energy and momentum require the presence of a third

* This short article by Mr. Shepherd should be regarded as an appendix or postscript to the series: "The Atomic Rocket," which he wrote in collaboration with Mr. Cleaver and which was published in the September and November, 1948, and the January and March, 1949, B.I.S. *Journals*. The present note reports certain further investigations made by Mr. Shepherd at the same time as the main article was being prepared.

body, if the gamma photon is to be completely absorbed. As a result, these effects are most marked in heavy materials such as tungsten, gold, lead, bismuth and uranium, for the massive nuclei of these substances greatly increase the probability that the gamma photon will be completely absorbed.

The Compton effect depends only upon the number of electrons available in the absorbing material and mass for mass the elements of light atomic weight will prove more effective than the heavy elements, in so far as they have more electrons per unit mass.

The accompanying curve, Fig. 1, shows the absorption coefficient of lead as being typical of that for the very heavy elements. The dotted lines show the contribution of the three main absorption effects. It will be observed that between 2 and 5 Mev the absorption is due mainly to the Compton Effect, and as a result, there is little to be gained in this region by using heavy elements, though for "softer" or "harder" X-rays the latter are much more effective.

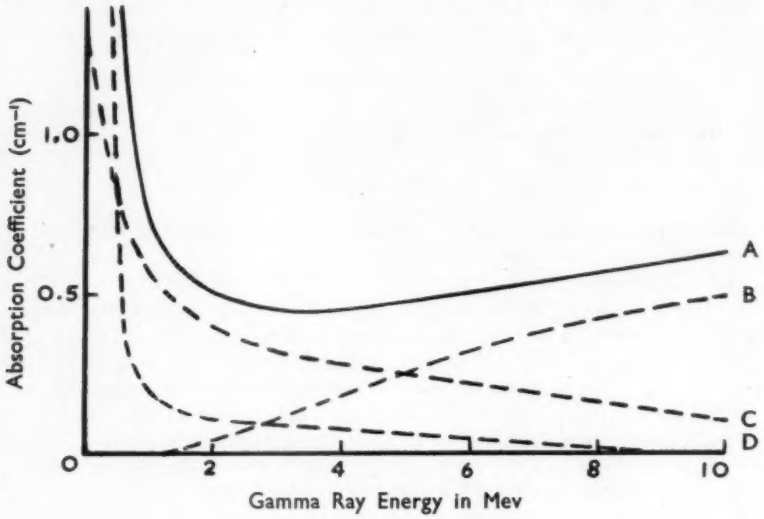


FIG. 1

(A) Total. (B) Pair Production. (C) Compton. (D) Photoelectric.

The mass absorption coefficient μ/ρ is substantially the same for all elements in the region near the minimum of the lead absorption curve. This coefficient has a value of about 0·04 cm.²/grm. at this point and does not vary here by more than about 10 per cent. over the whole range of elements. We may assume then that an absorption coefficient of 0·04 cm.²/grm. covers the worst possible case in the absorption of gamma radiation from a nuclear propulsion unit. On this basis the maximum thickness of absorber required to reduce the gamma ray intensity by a factor of 10 will be approximately 60 grm./cm.²

or 0·6 metric tonnes per square metre. A reduction by the factor 10^n will require 0·6 n tonnes per square metre.

It should be noted that the absorption coefficient 0·04 cm.²/grm., assumes that a gamma photon is completely lost after making a Compton Collision. This, of course, is not the case, but it is a reasonable assumption in the case of thick absorbers, because the scattered gamma photon is of a much lower energy than the incident photon and is very easily absorbed as a consequence.

We shall, therefore, assume that the figure 0·6 tonnes per square metre, is a maximum value of absorber thickness required to reduce radiation by a factor of ten.

To afford a complete shielding of the nuclear power plant we should have to surround it on all sides by absorbing material. This is obviously impossible for a rocket propulsion unit, since there must be an opening for the propulsive jet and indeed, this jet will itself be radioactive. For this reason one must be sure that the propulsion unit does not operate in the vicinity of external material which might scatter radiation into the living compartment (in the case of a manned rocket). This might require the use of chemical boosters in the vicinity of planetary surfaces or inside atmospheres, as indicated in Part I. Under such circumstances we can design our shield not to surround the propulsion unit but to throw a complete radiation shadow in a comparatively narrow cone enveloping the habitable compartment. We could, of course, attempt to surround the living compartment with shielding material, in which case the limitation on the use of the nuclear powered unit would be removed by making the compartment completely radiation tight. It is the first case that we shall consider here, however.

We visualise the rocket as a long tubular-shaped unit with the propulsion unit R (Fig. 2), shielding material S, propellant storage tanks P, and habitable compartment C. It will be assumed that the propellant occupies the whole cross section, so that it adds considerably to the shielding, and further, that the consumption of propellant results in a decrease in the length x of the propellant column though the full cross section is maintained. At first the propellant

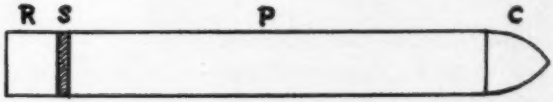


FIG. 2

will constitute a very effective shield on its own, but as it is used up the thickness of this shield diminishes until towards the final moments of operation it ceases to have any effect. Let us calculate its efficiency as a shield taking this into account, supposing that a certain amount of energy E_o would be received in the habitable compartment in the absence of any propellant, during the complete operation of the rocket: *i.e.* the rate at which energy is received in the compartment without the propellant shielding is given by

$$I_o = \frac{dE_o}{dt}$$

If the propellant thickness is x at some particular time, then I_o would be reduced to I where

$$I = \frac{dE_o}{dt} \exp(-\mu_p x)$$

μ_p being the absorption coefficient of propellant. The total energy received in the compartment while the whole column is used up is simply:—

$$\int_0^{t_o} I dt = I_o \int_{x_o}^{0} \frac{\exp(-\mu_p x)\, dx}{dx/dt}$$

If the thrust is constant, I_o and dx/dt will be constant, but in any case the ratio $I_o/dx/dt$ may be taken as constant, since this merely states that the energy escaping from the propulsion unit is proportional to the rate at which fuel is being used up.

Thus,

$$\int_0^{t_o} I dt = \frac{I_o}{\mu_p dx/dt} [1 - \exp(-\mu_p x_o)]$$

In practice, $\mu_p x_o \gg 1$ and so the second term in the brackets vanishes. Also with our constant thrust

$$\frac{dx}{dt} = \frac{x_o}{t_o}$$

and

$$E_o = I_o t_o.$$

So the energy received in the compartment is given by the ratio

$$E = \frac{E_o}{\mu_p x_o}$$

Thus the propellant reduces the energy received in the compartment by the factor $1/\mu_p x_o$.

Radiation Dosage in the Compartment

If ν is the absorption coefficient in living tissue of radiation of the particular energy we are considering and we have an incident intensity of

J (Energy flux/unit area — ergs./sq. cm./sec.),

then the dissipation in each unit volume of tissue neglecting self-shielding is given by the quantity ν J (ergs/c.c.). The energy is dissipated in producing ionisation and dissociation and these effects are believed to be the agencies which produce the destruction of the tissue.

It is conventional to measure radiation dosages in Roentgens or r units, one Roentgen corresponding to a dissipation of 83 ergs/c.c. in the tissue.* There exists much doubt as to what constitutes a safe dosage of radiation, but one can set some limits as to what is definitely safe or definitely dangerous. The

* This assumes that the tissue is effectively water of density 1·00 grm. per c.c.

dosages which are applied in Radiotherapy and which often amount to 1,000 *r* in very limited regions of the body, may be regarded as definitely lethal when received over an extended volume of the body, since such dosages are intended to destroy cells. On the other hand, it is not unusual for radiation workers to receive by accident dosages of several *r* in a short period and to suffer no permanent injury. For this reason we shall set a rather arbitrary upper limit of 10 *r* on the amount of gamma radiation absorbed by human payloads over the whole period of operation of the rocket, with the proviso that the actual dosage should be made much less if possible.

Now suppose W is the total useful energy dissipated in the rocket propulsion unit during the full course of operations. This is given by

$$W = \frac{M_o v_e^2}{2} [1 - exp\ (- v_c/v_e)]$$

where v_e is the exhaust vel., v_c is the characteristic velocity (q.v.).

In fact, we may take as sufficient approximation:—

$$W \simeq M_o v_e^2.$$

The amount of penetrating radiation from the power unit will be some fraction K of this. Further, if l is the distance between the centres of propulsion unit and the compartment, l being assumed much larger than the dimensions of propulsion unit or compartment, then we get a falling off of flux according to the inverse square law, *i.e.* in the compartment:—

$$J_o \simeq \frac{K M_o v_e^2 \times 10^{16}}{4 \pi l^2} \text{ ergs/sq. cm./sec.}$$

v_e is here in km./sec. and M*o* in tonnes. If we bring in the propellant shielding factor, this means that the radiation dosage in the absence of further shielding is given by:—

$$D \simeq \frac{K M_o v_e^2 \nu \times 10^{16}}{330 \pi l^2 \mu_p x_o} r \text{ units.}$$

To a sufficiently good degree of approximation we may take $x_o = l$ and $\mu_p = \rho_p \nu$ (ρ_p being the propellant density). This latter assumption merely implies that the mass absorbtion coefficients are the same for propellant and tissue and that the density of tissue is unity (a fairly accurate assumption especially in our 2–5 Mev range). Then:—

$$D \simeq \frac{K M_o v_e^2 \times 10^{10}}{330 \pi l^3 \rho_p} r \text{ units.}$$

In this last expression, l is in metres, ρ_p in tonnes per cubic metre. It is this quantity D, which must be reduced to our arbitrary 10 *r* by the introduction of a shielding factor f. This gives:—

$$f < \frac{3{\cdot}3 \pi l^3 \rho_p}{K M_o v_e^2} \times 10^{-7}$$

It is useful to introduce a factor η defined by:—

$$\eta = l/R$$

where R is the radius of the cylinder which represents the rocket structure. Under these circumstances, we have approximately:—

$$M_o = \pi l^3 \rho_p / \eta^2.$$

This idealises the rocket by representing it as a cylinder of length l equal in density to the propellant. It is, nevertheless, a good approximation for our purposes. Introducing this value for M_o, we find:—

$$\log_{10} f = -7 + \log_{10} (3{\cdot}3\ \eta^2 / K\ v_e^2).$$

This equation shows that, to reduce f and hence the weight of shield to a minimum, we must have η as great as it can be made subject to structural considerations. However, in so far as the weight of shield is $\propto -\log_{10} f$, we see that this weight is not particularly sensitive to variation in η, K or v_e. With $v_e = 10$ km. per sec. one can probably make the term on the R.H.S. as great as $+2$, or possibly higher. Thus, if K was 3·3 per cent. for example, we should have to make $\eta \geqslant 10$ to do this. We should then have:—

$$\log_{10} f = -5.$$

We have already seen that a thickness of 0·6 n tonnes per square metre is likely to be required to effect a reduction by 10^n so that the above factor would imply a thickness of 3 tonnes per square metre. We shall use this value as the total weight of health shielding required for safety in the remaining calculations.

Effect on Mass Ratio

It is obviously desirable, if we are to maintain a good mass ratio, that the quantity:—

$$S = \frac{\text{Shield weight}}{\text{Propellant weight}}$$

should be kept as low as possible, *i.e.*:—

$$S \ll 1.$$

Using the value of 3 tonnes/sq. metre which we have already derived for the shield thickness, we find for our cylindrical rocket, assuming the same cross section for shield and propellant column, that:—

$$S = \frac{3}{\rho_p x_o}.$$

Again, making the approximations $x_o = l$, etc., we find:—

$$l\rho_p = \left[\frac{M_o \eta^2 \rho_p^2}{\pi}\right]^{1/3} = \frac{3}{S}$$

so that

$$M_o = \frac{27\pi}{\eta^2 \rho_p^2 S^3} \text{ tonnes.}$$

Obviously we must not let $\eta^2 \rho_p^2 S^3$ become too small, otherwise the rocket will need to be of excessive mass.

Let us take as an example $\eta = 10$ and $S = 1/20$ (the latter figure being about the maximum permissible if we wish to preserve comparable mass ratios to those which may be obtained in conventional rockets). We should then have:—

$$M_o = 6{,}800/\rho_p^2 \text{ tonnes.}$$

It will be observed that this leads to a fantastic mass in the case of a substance like hydrogen when we should have:—

$$M_o = 1{\cdot}4 \times 10^6 \text{ tonnes.}$$

With some sacrifice in mass ratio we might make $S = 1/10$ and $\eta = 20$ and under these circumstances, we should have:—

$$M_o = 210/\rho_p^2 \text{ tonnes.}$$

So that even under these extreme conditions we should have the excessive value of:—

$$M_o = 43{,}000 \text{ tonnes}$$

—for a liquid hydrogen filled rocket. It would appear that there is little hope of solving the shielding problem in the case of a rocket working with hydrogen. However, it is worth noting that there are loopholes, which permit us to escape from the excessive masses which resulted in the above calculation. To do this we should try and make the mean cross section of the propellant column a_p greater than the mean cross section of the shield a_s, when we have:—

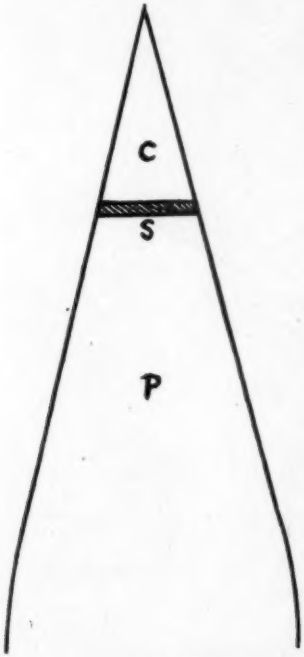


FIG. 3

$$S = \frac{3a_s}{\rho l a_p}$$

and

$$M_o = \frac{27\pi a_s^3}{\eta^2 \rho_p^2 S^3 a_p^3}$$

It might well be possible to make a_s^3/a_p^3 as low as 2 per cent., for example, by having a small conical life compartment in the nose of the rocket as in Fig. 3.

This reduction in area would be more difficult to attain at the base where the size of the propulsion unit would have to be commensurable with the size of the rocket and the shielding area correspondingly large. However, we need only put sufficient shielding near the base to prevent overheating of the propellant—probably less than 1 tonne/square metre, the rest could go at the compartment end as illustrated. Indeed, in the case of a high boiling-point propellant, it might be possible to dispense with the

energy shield entirely by circulating the fluid through a base tank immediately prior to pumping it into the propulsion unit. Such would be the case with water or the higher paraffin hydrocarbons as propellant but probably not with liquid hydrogen.

It seems clear that even with the improvements in the ratio a_s/a_{sp}, a thousand tonne rocket using liquid hydrogen could only be possible if we had at least 10 per cent. of the propellant weight as shielding and even then we might have to adopt an inconveniently long narrow structure.

The case of liquid deuterium ($\rho = 0{\cdot}17$) would be somewhat better, masses working out at one-sixth of those for hydrogen in the case of the same η and S values.

For liquid ammonia, water and the hydrocarbons, the results are far more favourable and there is little reason why the addition of shielding material should have an appreciable adverse effect on the mass ratios. Fig. 4 shows the variation of structural factor, $\eta^{2/3}\, a_p/a_s$ on the propellant to shield mass ratio, for a 3 tonne/sq. metre shield in a 1,000 tonne rocket, and for various possible propellants.

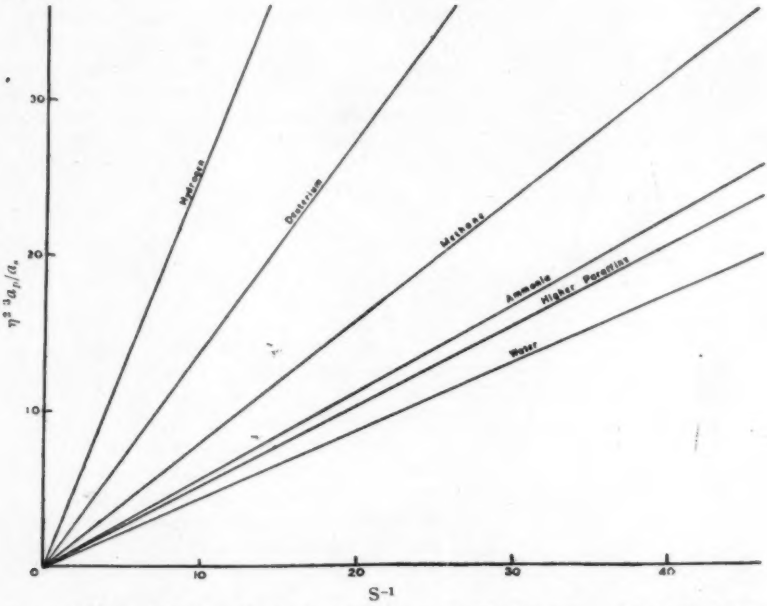


FIG. 4. Structural Factor $\eta^{2/3}a_p/a_s$ for 1,000 Tonne Rocket with 3 Tonnes/Metre^2 Shield.

Nuclear-Chemical Step-Rocket

An interesting possibility exists for eliminating shielding, especially in the case of a propellant with high boiling point and high latent heat, where no

energy shield may be required. This involves the use of a step rocket, in which the final step is a chemical one containing the life compartment. The propellants in this final chemical rocket would now act as the shield to the life compartment which would form the payload of this conventional rocket.

The "atomic rocket" in this case would act purely as a booster step, being finally detached when all the "atomic propellant" was expended, the remainder of the flight being carried out by the conventional unit. The advantage of such an arrangement would be that the "shield," no longer dead weight, would contribute to the total characteristic velocity of the rocket; under these conditions a value of $S = 1/10$ would be quite permissible, since this would be useful payload instead of structural dead weight. An additional advantage of the scheme that we have outlined is that which K. W. Gatland has raised, viz.: that it might be inconvenient to land the awkward structure of an atomic rocket, whereas the conventional rocket, with a greater flexibility of design, could be made to incorporate all the features required in a landing rocket.

There might, of course, also be a chemical third step, below the atomic booster, to eliminate radiation dangers at take-off.

REFERENCE

(1) Heitler, *Quantum Theory of Radiation.*

METEORS AS A DANGER TO SPACE-FLIGHT

By Arthur C. Clarke, B.Sc.

The possible danger to spaceships from meteors is one of the objections which has been raised against space-flight on innumerable occasions, and is a subject on which widely varying statements have been made. On the one hand it has sometimes been suggested that a rocket would be riddled by cosmic particles as soon as it left the atmosphere: on the other, it has been asserted that the danger from meteoric bombardment is so small as to be unworthy of notice. It seems probable that, as is usually the case, the truth will be between these extremes: but until recently no quantitative estimates of the matter were generally available.

A detailed study of this important question has now been published[1] by G. Grimminger of the Missiles Division, Rand Corporation, and the following précis of his results is given with his permission. (We are also grateful to him for Figs. 1 and 2.) It is of some interest to note that Mr. Grimminger's paper is based on a report to the Douglas Aircraft Company dated May, 1946: Defence Secretary Forrestal's statement that the United States was interested in space-stations was not made until December, 1948.

The fundamental fact in the problem is the number of meteors of all sizes hitting the earth every 24 hours. This has been calculated from visual observations and by extrapolation down to sub-visual magnitudes (see *e.g.* Ovenden[2]). It is possible that a revision of the values obtained may be necessary as a result of radar observations, but meanwhile Table I, due to Watson, may be taken as authoritative. The table shows (1) the visual magnitude of the meteor, (2) the

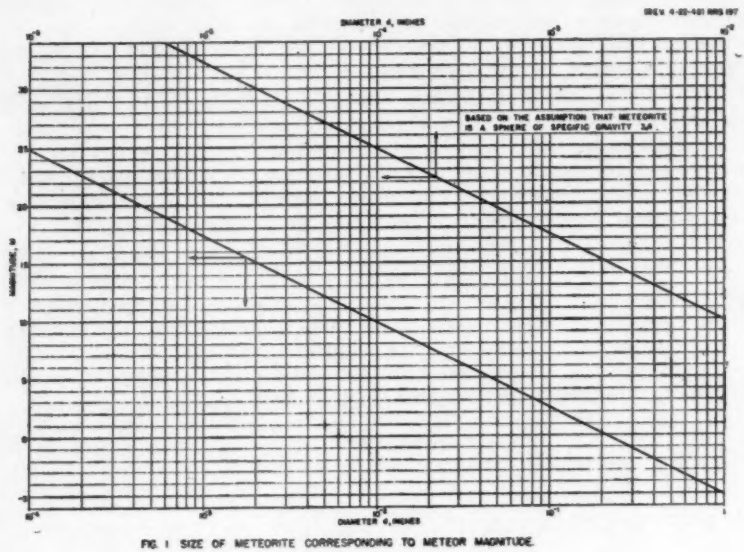

DIAMETER d, INCHES
BASED ON THE ASSUMPTION THAT METEORITE IS A SPHERE OF SPECIFIC GRAVITY 3.6
MAGNITUDE, M
DIAMETER d, INCHES

FIG. 1 SIZE OF METEORITE CORRESPONDING TO METEOR MAGNITUDE.

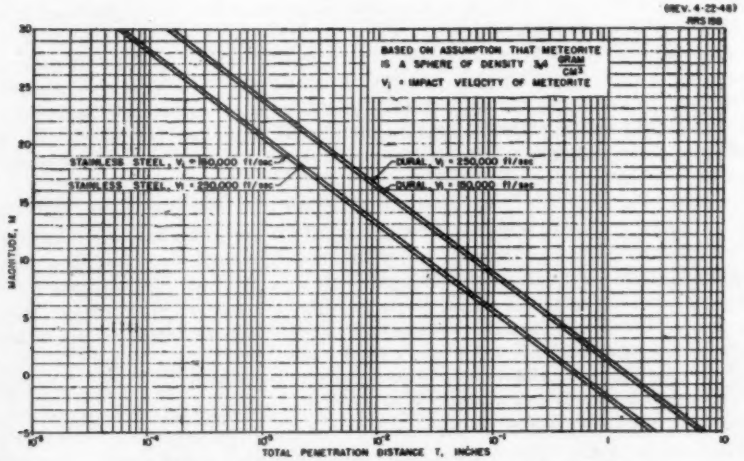

BASED ON ASSUMPTION THAT METEORITE IS A SPHERE OF DENSITY 3.6 GRAM/CM³
V₁ = IMPACT VELOCITY OF METEORITE
STAINLESS STEEL, V₁ = 150,000 ft/sec
STAINLESS STEEL, V₁ = 250,000 ft/sec
DURAL, V₁ = 250,000 ft/sec
DURAL, V₁ = 150,000 ft/sec
MAGNITUDE, M
TOTAL PENETRATION DISTANCE T, INCHES

FIG. 2 PENETRATION OF METAL PLATE BY IMPACT OF METEORITES

number of meteors of this magnitude, (3) the total number of meteors *down to this magnitude*, (4) and (5) the mass and diameter for each magnitude.

TABLE I

Visual magnitude	Number N	ΣN	Mass grm.	Diameter cm.
−3	28,000	28,000	4	1·3
−2	71,000	99,000	1·6	·97
−1	180,000	280,000	·6	·71
0	450,000	730,000	·25	·5
1	1,100,000	1,900,000	·1	·4
2	2,800,000	4,700,000	·04	·3
3	7,100,000	12,000,000	·016	·2
4	18,000,000	30,000,000	·006	·15
5	45×10^6	75×10^6	·002	·11
6	110×10^6	120×10^6	·001	·08
7	280×10^6	470×10^6	·0004	·06
8	710×10^6	$1{,}200\times10^6$	·0002	·05
9	18×10^8	30×10^8	·00006	·03
10	45×10^8	75×10^8	·000025	·02
15	45×10^{10}	75×10^{10}	$2{\cdot}5\times10^{-7}$	·005
20	45×10^{12}	75×10^{12}	$2{\cdot}5\times10^{-9}$	·001
25	45×10^{14}	75×10^{14}	$2{\cdot}5\times10^{-11}$	·0002
30	45×10^{16}	75×10^{16}	$2{\cdot}5\times10^{-13}$	·00005

The table reveals a number of very interesting facts. In the first case, meteors of over 1 cm. diameter are so rare as to be negligible. On the other hand, for smaller sizes the numbers are enormous, rising eventually into the thousands of billions. (The figures of a few score million a day that have sometimes been quoted against space-flight are fantastic *under-estimates*!) Table I stops at magnitude 30, since meteoric dust below this size would be swept out of the earth's orbit by radiation pressure. The magnitude-diameter relation for meteors of the stony type (which are believed to be 10 times as common as iron ones) is shown in Fig. 1.

It is now necessary to consider how far down the magnitude-scale one must go until meteors are too small to be dangerous. This cannot be easily determinded since it depends on the material and thickness of the hull, the type of meteor (iron or stone) and the velocity of impact. The laws of impact at hypersonic velocities are also somewhat uncertain, and it is perhaps unsafe to extrapolate from ballistic data at much lower speeds.

Grimminger assumes that the average meteor speed is 150,000 ft./sec. (45 km./sec.) and that the maximum is 250,000 ft./sec. (75 km./sec.), which is parabolic speed at the earth's orbit. He then derives curves (Fig. 2) showing the thicknesses of dural and steel which would be penetrated by stony meteors of any magnitude, travelling at these velocities. It will be noticed that the penetration is surprisingly unaffected by the change in velocity.

For a dural hull of the thickness employed in normal aircraft construction (thickness ·02–·05 in.) stony meteors down to mag. 14 might penetrate, while the rarer iron meteors could be dangerous down to mag. 16. For a steel hull,

TABLE II

PROBABILITY OF A METEORITE HIT

(Based on Total Number of Meteors down to Given Size)

Magnitude	−3	0	5	8	10	12	14	16
Average number of hits per hour ..	$1{\cdot}86\times10^{-10}$	$4{\cdot}78\times10^{-9}$	$4{\cdot}90\times10^{-7}$	$7{\cdot}75\times10^{-6}$	$4{\cdot}90\times10^{-5}$	$3{\cdot}10\times10^{-4}$	$1{\cdot}96\times10^{-3}$	$1{\cdot}23\times10^{-2}$
Average number of hours between hits	$5{\cdot}36\times10^{9}$	$2{\cdot}09\times10^{8}$	$2{\cdot}04\times10^{6}$	$1{\cdot}29\times10^{5}$	$2{\cdot}04\times10^{4}$	$3{\cdot}23\times10^{3}$	$5{\cdot}11\times10^{2}$	$8{\cdot}10\times10$
P_{1+} for 24 hours ..	$4{\cdot}47\times10^{-9}$	$1{\cdot}15\times10^{-7}$	$1{\cdot}18\times10^{-5}$	$1{\cdot}86\times10^{-4}$	$1{\cdot}18\times10^{-3}$	$7{\cdot}42\times10^{-3}$	·0459	·2564
T (0·5) hours ..	$3{\cdot}72\times10^{9}$	$1{\cdot}45\times10^{8}$	$1{\cdot}41\times10^{6}$	$8{\cdot}95\times10^{4}$	$1{\cdot}41\times10^{4}$	$2{\cdot}24\times10^{3}$	$3{\cdot}58\times10^{2}$	$5{\cdot}62\times10$
T (0·99) hours ..	$5{\cdot}39\times10^{7}$	$2{\cdot}10\times10^{6}$	$2{\cdot}05\times10^{4}$	$1{\cdot}30\times10^{3}$	$2{\cdot}05\times10^{2}$	$3{\cdot}24\times10$	5·18	·814
T (0·999) hours ..	$5{\cdot}37\times10^{5}$	$2{\cdot}09\times10^{5}$	$2{\cdot}04\times10^{3}$	$1{\cdot}29\times10^{2}$	$2{\cdot}04\times10$	3·23	·516	·081

P_{1+} : probability of at least 1 hit.
T (0·5): time interval to give a 50/50 chance of being hit.
T (0·99): time interval to give a 100/1 chance of being hit.
T (0·999): time interval to give a 1,000/1 chance of being hit.

Assumed area of body = 1,000 sq. ft.

the limiting magnitudes are 11 and 13. This means that in the most unfavourable cases meteors only a few thousandths of an inch across might be dangerous, but this fact by itself means nothing until the numbers of such meteors are taken into account.

Grimminger next employs statistical theory to derive some extremely interesting tables for the case of a body 300 miles from the surface of the earth and with a planform area of 1,000 square feet (about five times that of V.2). The following factors are tabulated for meteors of various magnitudes:—

(1) Average number of hits per hour.

(2) Average number of hours between hits.

(3) The probability that there will be *at least* one hit per 24 hours.

(4) The "waiting time" for a 1 : 1 chance of *not* being hit.

(5) The "waiting time" for a 100 to 1 chance of *not* being hit.

(6) The "waiting time" for a 1,000 to 1 chance of *not* being hit.

Two tables are given, the first showing the above values for meteors of any given magnitude, the second showing them for *all* meteors down to any given magnitude. The latter being the table of more practical interest is the one part of which is reproduced here.

From this table one may obtain an approximate idea of the danger from meteors on any given voyage. Assuming that a spaceship had a dural hull ·04 in. thick, we see from Fig. 2 that meteors down to mag. 12 must be considered. Table II shows that there will be, on the average, one penetration per 3,000 hours: or putting it another way, on the 100 hour lunar trip there will be 1 chance in 30 of being hit. This is an appreciable risk, but the following points must also be considered. A somewhat thicker hull would reduce the danger by a very considerable factor, and a puncture would only be dangerous in relatively limited areas which could easily have special protection. (The pressurised portion of a spaceship would be only a very small volume of the whole machine—its planform area would certainly be much less than 1,000 sq. ft.) To take a specific example, if the skin was $\frac{1}{8}$-in. steel, then it would need a fifth magnitude meteor to penetrate it. There would be less than one chance in ten thousand of this happening on a lunar voyage.

The matter is obviously more serious when long voyages or permanent orbital structures are considered. If one was prepared to use $\frac{1}{4}$-in. steel over the assumed 1,000 sq. ft. of hull (this would involve a weight of about 30 tons) meteors down to zero magnitude could be guarded against, and there would then be one penetration every 30,000 years or so! Thus armour would be a possible, though expensive, remedy.

However, F. L. Whipple has pointed out that there is another solution to the problem. In a paper to the American Astronomical Society in September, 1946[3] he calculated that a 12 ft. diameter spaceship with $\frac{1}{4}$-in. steel walls would be penetrated once every 50 years by meteors down to 8th magnitude. This result is somewhat more pessimistic than Grimminger's, as Whipple has assumed that the meteor would melt its way through the hull. Grimminger has shown that this would not be the case owing to the very short time intervals involved;

thermal transfer is much slower than momentum transfer. Whipple mentions that his assumptions represent an extreme case and goes on to say:

> "Although the probability of meteor penetration is small, a simple protection can be provided. . . . Considerations of conservation of momentum and energy show that when a meteorite collides with a sheet of thickness comparable to its diameter the result is an explosion in which both the meteorite and the corresponding material of the sheet are vaporised and ionised at very high temperatures. Hence a 'meteor bumper' consisting perhaps of a millimetre-thick sheet of metal surrounding the ¼-in. skin of the space-vessel at a distance of an inch would dissipate the penetrating power of meteors several times larger than one corresponding to an eight magnitude meteor."

To sum up, then, it seems that in the light of our present knowledge it is probably not worth while taking any special precautions against meteors for relatively short voyages such as the journey to the Moon. For space-stations or interplanetary rockets, meteors probably represent a real danger, but it is one which can be neutralised, or at least very greatly reduced, by fairly simple means.

REFERENCES

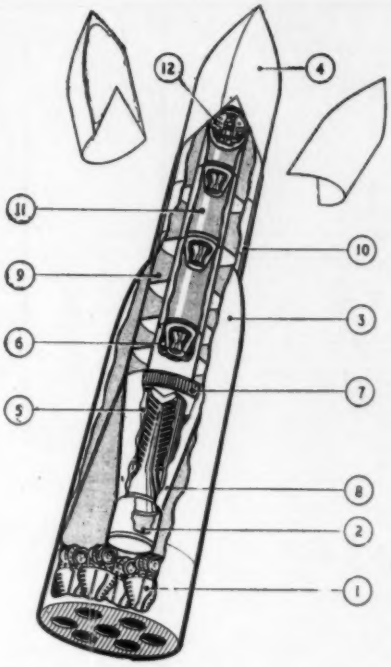
(1) G. Grimminger, "Probability that a Meteor will Hit or Penetrate a Body situated in the Vicinity of the Earth," *J. App. Phys.*, **19**, 947–56 (Oct., 1948).
(2) M. W. Ovenden, "The Nature and Distribution of Meteoric Matter," *J.B.I.S.*, **6**, 157–73 (Sept., 1947).
(3) Abstracted in *Astronomical Journal*, Feb., 1947, p. 131.

THE MODEL PROGRAMME

Introduction

We are reproducing, in this issue of the *Journal*, a cut-away illustration and details of the design, by certain members of the Technical Committee, of a Circum-Lunar Rocket, employing a hypothetical nuclear-powered propulsion unit. This is to form the basis of one of the models which members of the Society are constructing to illustrate possible developments in space-flight.

The principal object of this design study is to show how power plants of certain assumed performance could be incorporated into a compact unit, capable of attaining one of the initial targets in the conquest of interplanetary space. Such a design may well prove to be far from the mark when a lunar rocket is eventually built, since the structure will be very greatly dependent upon the performance of the propulsion units available, about which we can, as yet, do no more than make rough guesses. However, it is the general feeling of the Technical Committee that this design, and models based upon it, should prove useful in illustrating, particularly to the layman, some of the possibilities and principles which may be involved in the construction of manned space-rockets.



Key to Principal Features :—

(1) Chemical booster—seven motors of 450 tonnes thrust, using liquid oxygen/liquid hydrogen. V_e assumed = 4 km./sec.
(2) Fuel for booster pumps.
(3) Expendable tanks for chemical booster (annular type).
(4) Expendable tanks for chemical booster (cylindrical type).
(5) Atomic reactor: 1,100 tonnes thrust, using ammonia propellant. Weight, 40 tonnes. V_e assumed = 10 km./sec.
(6) Turbo-pump feed to reactor.
(7) Energy shielding—weight, 20 tonnes; density, 1 tonne per metre.^{2}
(8) Gyro-regulated steering jets, incorporating steam exhaust from turbo-pumps.
(9) Expendable tanks for atomic propulsor (annular type).
(10) Jointed main longerons.
(11) Three-step chemical crew rocket, using liquid oxygen/liquid hydrogen. Weight, 60 tonnes, all-up. V_e assumed = 4 km./sec. (Serving also as health shielding during operation of atomic reactor—density, 6·25 tonnes per metre.^{2})
(12) Pressurized crew chamber. Weight, 1·4 tonnes, including crew, instrumentation, provisions, etc.

The design has been based on the assumption that a nuclear-powered rocket can be developed capable of giving an exhaust velocity of 10 km./sec., with a fairly dense propellant material. It remains to be seen whether such a unit can be devised and constructed. Many people (including our good friends of the Pacific Rocket Society) will be inclined to regard this assumption as too optimistic. Perhaps this is the case, but no less optimistic is the suggestion

Vehicle	Propellant	No. of expendable tanks, or steps	No. of motors (tonnes thrust)	Assumed exhaust velocity (km./sec.)	Propellant mass (tonnes)	Gross mass (tonnes)	Payload mass (tonnes)	Mass ratio (actual)	Thrust (tonnes)	Firing time (secs.)	Estimated length (metres)	Estimated hull dia. (metres)
Overall project	—	—	—	—	808 (Total)	1,240	1·4 (Final)			585–618	58	10
Booster ..	Oxygen–hydrogen	Single step, 2 expendable tank stages	7 × 450	4	420	1,240	562	1·91	3,150	54–57	58	10
Atomic propulsor	Ammonia	Single step, 7 expendable tank stages	Single reactor 1,100	10	347	562	60	2·63	1,100	313–325	37	7
Crew rocket ..	Oxygen–hydrogen	3 steps	—	—	41	60	1·4 (Final)	3·16	—	218–236	19·5	3·5
1st Step ..	Oxygen–hydrogen	—	1 × 200	4	21	60	30	1·54	200	43–46	—	3·5
2nd Step ..	Oxygen–hydrogen	—	1 × 75	4	14	30	10	1·87	75	76–80	—	3·5
3rd Step ..	Oxygen–hydrogen	—	1 × 25	4	6	10	1·4	2·50	25	99–110	—	3·5

$$\text{Structural factor} = \frac{\text{Structure wt.}}{\text{Structure wt.} + \text{Propellant wt.}}$$

Booster	.. ..	0·382
Atomic	.. ..	0·306
Chem. 1st	.. ..	0·30
2nd	.. ..	0·30
3rd	.. ..	0·30

CHARACTERISTICS OF 1,240 TONNES EXPENDABLE/STEP ROCKET (PRELIMINARY DATA)

NOTES: The final velocities listed are additive, giving a characteristic velocity for the overall project of 20·45 km./sec. This is sufficient to accomplish a lunar circumnavigation for a flight ending in a circumterrestrial orbit, making full allowances for drag and "g" losses, and for course corrections, safety margins, etc., in space.

Vehicle	Effective mass ratio	Final velocities neglecting "g" and drag (km./sec.)	
Booster	1·55	1·75	Total velocity
Atomic propulsor ..	2·94	10·8	12·55
Crew rocket ..	7·20	7·9	20·45

that a manned circum-lunar rocket of reasonable initial mass could be constructed to incorporate propulsion units of much lower performance.

One final point should be emphasized before giving the details of this rocket: that is, that the design is only a first approximation to a lunar rocket. It is intended that there should be further approximations in future years and it is hoped that these may be found to converge gradually on to the eventual reality.

The Expendable Step "Earth Escape" Rocket
(to complete a circumnavigation of the Moon, with crew of three)

Following the recommendations contained in two recent papers by K. W. Gatland ("Expendable Rockets" and "Rockets in Circular Orbits"), a group of the Technical Advisory Committee, comprising Messrs. K. W. Gatland, A. M. Kunesch, A. E. Dixon and R. E. Webb—in collaboration with the Technical Director, L. R. Shepherd—have commenced a design analysis of "Earth Escape" rockets, utilizing orbital stage technique. The design illustrated forms the basis of the study which will be considered at greater length in a lecture to the Society in the 1949–50 programme.

The Circum-Lunar Rocket

The vessel under consideration is intended to obtain a lunar circumnavigation *without* refueling in a sub-orbit of the Earth, using the following sequence:—

Booster to clear atomic vehicle from the atmosphere to approximately 1·75 km./sec. velocity.

Atomic Propulsor: 1·75 km./sec. to orbital velocity.

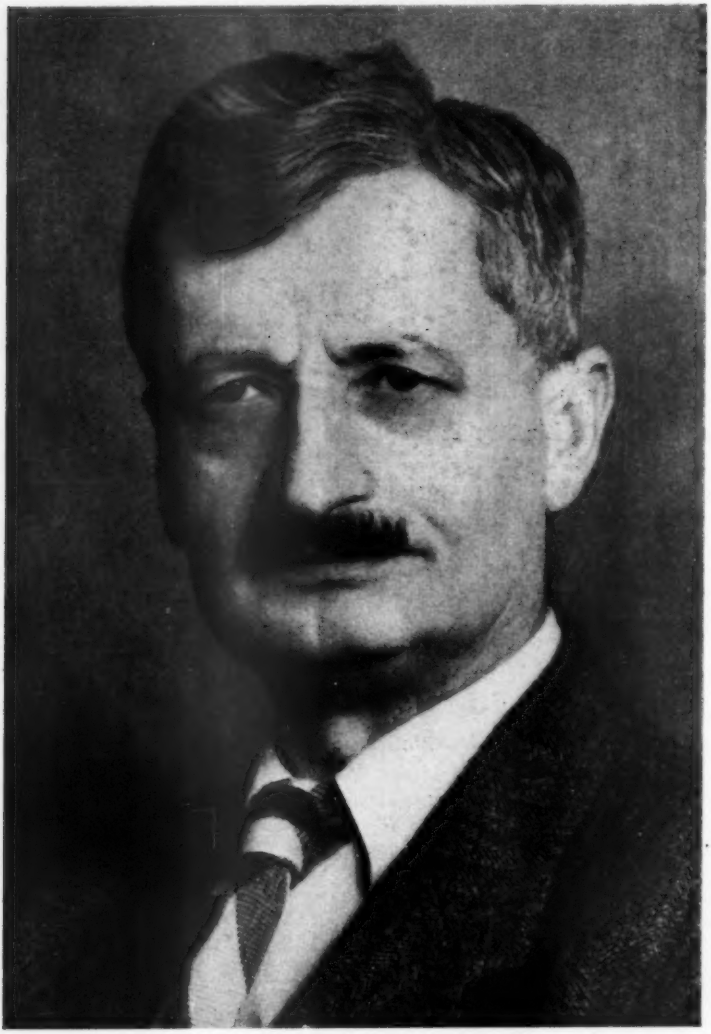
Crew Rocket from orbital velocity to release velocity, circumnavigation of Moon and return to orbit Earth.

Landing by secondary rocket previously brought up from Earth to provide braking down to a velocity permitting final parachute descent by crew chamber.

Note on Expendable Construction

Structural considerations suggest that *expendable* construction may have advantages over the pure "step" arrangement in large multi-engine chemical rockets or in projects embodying an atomic reactor, and some early thoughts on this subject have appeared in the *Journal* ("Expendable Rockets," July, 1948, p. 160). The proposal is to break down the forward portion of the hull into separate tank stages which jettison progressively as propellant consumes. Each stage consists of two half-cylindrical tank bays with integral structure which, on assembly, form an efficient hull. The component tanks are locked together with explosive ties and pressure balance is provided between them, allowing the use of light diaphragms for the backing panels.

The separate stages have conic-form nosing, both to afford some streamlining effect in the early part of the ascent and to provide a light method of jointing, since all tanks are faced together. It is proposed to transmit the *end loads* mainly through external jointed longerons to which the tanks are directly anchored.



Professor Hermann Oberth.

PROFESSOR HERMANN OBERTH

At the meeting of the Council on 12th February, 1949, it was unanimously agreed that an invitation be extended to Professor Hermann Oberth to become the first Honorary Fellow of the Society, in recognition of his great pioneering activities in the field of rocket research.

We believe that many of our members would like to know more about Professor Oberth's career, especially in recent years, and accordingly we are printing the following brief sketch.

Professor Oberth was born on 25th June, 1894, at Hermannstadt, in Transylvania, and began his scientific studies at Munich in 1913. He fought in the 1914–18 war and was wounded in 1915, after which he became an ambulance sergeant at a military hospital in Schässburg, Transylvania, where he remained until the end of the war. This gave him the opportunity to resume his interrupted studies and to take up his astronautical investigations: at this time he also explored the psychological effects of weightlessness (see *Wege zur Raumschiffahrt*, p. 102 *et seq.*). From the end of the war until 1923 he continued his studies at the universities of Klausenburg, Munich, Göttingen and Heidelberg, obtaining the diploma of professor in 1923. In the same year his *Die Rakete zu den Planetenräumen* was published by R. Oldenbourg in Munich.

He began his teaching career at Schässburg, moving to the high school at Mediasch in 1926, where he remained until 1938. During 1928–31 he was on leave for research and stayed mainly in Berlin, where he worked on the film "Frau im Mond," and also conducted his first experiments with liquid air. One of his assistants at that time was Wernher von Braun, later technical director at Peenemünde. *Wege zur Raumschiffahrt* was written during this period and appeared in 1929.

Oberth's work at Berlin showed him the great importance of practical engineering experience, and for a while he left his theoretical studies to concentrate on machine design and similar matters. From 1933, in addition to his main work, he was in charge of a training school for mechanics.

In 1938 he was appointed a professor at the Technische Hochschule in Vienna, to carry out secret experimental research work. Two years later he was transferred to Dresden to direct a section designing fuel pumps for the future V.2. In 1941 he went to Peenemünde, where his work consisted of examining all ideas and projects from other fields which might be of value to rocket technology. He also made calculations in connexion with step- and long-range rockets (see this *Journal*, p. 241–2, November, 1948). Professor Oberth also prepared a report on large, guided A.A. rockets employing solid fuels as propellant.

In December, 1943, he went to the Reinsdorf factory of the Westphälisch-Anhaltische Sprengstoff A.G. (WASAG) to develop these rockets. Considerable technical problems were encountered and overcome, and Professor Oberth believes that rockets of this type have considerable possibilities, both for military purposes and as lower steps for space-ships and long-range rockets.

After the war he was detained for four months in a camp with the engaging

name of "Dustbin," and when released went to live at Feucht, near Nuremburg, where he had purchased a house and some land in 1943. Since 1945 he has lived there with his family, cultivating his farm and doing advisory scientific work.

KNOW YOUR COUNCIL

JOHN HUMPHRIES, B.Sc. (Eng.), A.M.I.Mech.E., A.F.R.Ae.S. Born 1922, and educated at Farnborough Grammar School. In 1938 was apprenticed to the Royal Aircraft Establishment at Farnborough, where he obtained his Higher National Certificate in Mechanical Engineering. This was followed by part-time studies at Northampton Polytechnic, where he obtained an Honours degree in Engineering in 1946.

After completing his apprenticeship in 1943, Mr. Humphries worked on the vibration and fatigue of aircraft gas turbine blading and flight vibration problems of aircraft. He transferred to rocket research in 1946, and was connected with the development of the Vickers Transonic rocket motor. Since August, 1947, he has been in charge of liquid oxygen rocket motor research and development at the Ministry of Supply Rocket Propulsion Department at Westcott, where there is a strong nucleus of B.I.S. members.

Mr. Humphries first became interested in the possibilities of space-flight at the age of fourteen, through the medium of science fiction, and about a year later his interest was strengthened by the firm scientific groundwork of P. E. Cleator's *Rockets Through Space*. He is still a keen science fiction fan, and two of his secret ambitions are to own a space-yacht and an apartment in Luna City! He was an early member of the C.B.A.S., and formed a war-time branch of that society at Farnborough; subsequently he joined the B.I.S. and has served on the Council for the past three years.

One of Mr. Humphries' interests is librarianship, and while at the R.A.E. he acted for several years as Liaison Officer between his department and the Establishment's Library. At present he edits the "Abstracts" published by this *Journal* (which involves the reviewing of nearly 2,000 publications per annum), and also runs the photostat loan system, which, incidentally, he would like to see more actively used by members. His other interests include English poetry, music, films, walking, mountaineering and natural history.

K. W. GATLAND. Born 1924, educated Hollyfield Road School, Surbiton, and the Hawker Aircraft Technical School, Kingston-on-Thames. Joined the Hawker Design Staff in 1941. Has worked in the Production Drawing Office and now contributes technical articles dealing with aspects of Hawker design in an official capacity.

Mr. Gatland has also published a number of papers and articles on rocket development, some of which have appeared in the *Journal* of the B.I.S. His 100,000 word technical history, *Rocket Propulsion*, published by George Newnes, is probably the most extensive of its kind.

Was the founder, in 1941, of the Astronautical Development Society, a group of rocket enthusiasts which, in combination with the Manchester Astronautical Association, later became the Combined British Astronautical Societies', with a membership of over 400. He worked in close co-operation with Mr. Eric

Burgess, founder of the M.A.A., and leading members of the pre-war B.I.S., and was among the small group of technicians responsible for the re-birth of the present Society in 1945. A Fellow, he has been a member of our Council for the whole post-war period.

Mr. Gatland relates his interest in the movement as two-fold: first, the prospect of achieving (through space-flight) a less introspective, more "universal" outlook in human thought; and second, the intriguing technical problems involved. He suggests the main solution to the latter will be found principally in expendable atomic rockets, using chemical rockets in combination for landing, and has published schemes to this effect. [He developed the principle of expendable tanks in which the forward portion of the hull consists of separate tank stages which jettison successively, each with its supporting structure. The separate tank bays consist of two half-cylindrical tanks (backed by light diaphragms, with balanced pressure) held together with explosive ties. The method is equally applicable to large unrotating or rotating rockets of the type usually envisaged for space-flight and is mentioned in his paper, "Expendable Rockets." With Mr. H. E. Ross,* he was the first to advocate orbital technique as a means for achieving escape from the Earth and composite landing from a stable sub-orbit, in "Rockets in Circular Orbits."]

The achievement of interplanetary communication, beyond the guided missile, he believes will be exceedingly difficult and makes his guess at its realization as sometime in the last quarter of the present century.

* *Similar conclusions were reached in separate papers submitted to the B.I.S. in October,* 1948.

SIC ITUR AD ASTRA

By H. E. Ross

We fell: and as we fell the planets turned to watch, while one
more virile than the rest, whereof a myriad minds our quest was born,
guided our fall and cheered us on.

We fell: and as we fell the blazoned firmament revolved;
the candent crystal stars and sequined bannerettes
of far-flung misty radiance all wheeled about, but yet were still.
And Time was not, for night and day were one.

Then from their ancient thrones the gods looked down
in wonder and amaze, and leaned across and muttered each to each,
and trembled for their realms, and feared for their omnipotence—
yet stayed us not who dared the cosmic wilderness.

We fell: and as we fell the brooding loneliness of space
took demon shape and seized upon our souls, so that we longed
for solid ground beneath our feet, and yearned for home
and sight and fondling touch of loved ones, with a blue sky overhead.

But though in agony of heart we gazed aloft to where our native world
did dwindle to a crescent in the void, and though we counted all these
cherished things and life itself as lost unless we turned,
yet one o'ermastering passion greater than all else prevailed—
and still we fell.

Then, lo, the sheer untrammelled well of space below was filled,
and looking down we saw the lone refulgent orb that drew us from on high.

It grew, and as it grew it swallowed star on star, and feeding thus
waxed yet more great and nearer to our eyes. But still we fell,
while faster rose the greedy Moon to take us unawares.

No longer safe to let the Moon have sway, yet spellbound now
we gazed in awe upon the face of this enchanted world and heeded not
our fate. Where else in all the gravid spawn of this our lustrous
solar swarm such naked blaze of spectral lure and grand display
of ferine majesty? Where else these sleeping basalt seas,
these glassy tideless shores and scowling cliffs of brass?
Where else but here such wrack of rock, so many yawning crater pits,
such dazzling mountain spires enmeshed in stygian gloom? No small
similitude trapped in a lens or copied on a sheet, but Moon itself—
one hundred miles below! . . . And still we fell, while larger yet
and more intense the fiercesome pattern grew.

But now the saviour voice of instinct cried aloud that we must act
or die, and reeling back from this Medusan spell our minds broke free
to battle for our lives . . . A flash, a roar, and like a white-hot
mighty sword our jet unsheathed to hold the Moon at bay . . . Yet still
we fell.

But as we fell and sweated at our posts, and eyed the grimly bulking Moon
most fearfully, and as we thrust against the Moon with all the force
at our command, until the whole vast lunar weight seemed laid direct
upon our tortured breasts, and as with dimming sight and bated breath
we prayed—yes, prayed to God Most High for surcease from our peril—
so presently Moon's cruel embrace relaxed, its whelming rush declined,
and in the end this savage world was stayed.

So now with looming Moon subdued but still alert to wreck us
at the last, we edged towards our goal, and poised and plunged
and hung again and shook off mile by mile. Thus then most warily
we came, until at length the saw-toothed mountain peaks and topmost
crater rims rose level with our side.

Yet still we dropped, while all around the sky-borne grandeur
climbed in regal fantasy of castellated heights and bristling upswept walls.

Thus did we come, and thus did pass the lofty portals of the Moon,
with all the massed array of storied rampart chains—then sank below
until a sunbathed bulwarked plain appeared and spread and lifted into view.

One long last mile of anxious drop essayed with measured bursts
of throbbing fire, until anon our buoying ram of flame impinged
upon the lunar crust, boiling aloft the dust of ages there,
so that we plunged through raging smoke and vulcan twilight.
One aeon moment more of gaunt suspense, of wild heart-searing thrill—
till now—till now with grinding crash and heeling shock,
we struck the lunar soil!

Then all was still, and we were safely down upon the vanquished Moon.

So for a little while we rested, and were glad—for well we knew
that in this instant of exultant hush, the star-encrusted orb
and sceptre of the lunar realm did pass resplendent into the hands of Man.

Then, though we spoke it not as now we listened to the mighty voice
of Earth raised in proud paean to the aureoled Court of Worlds,
We wondered in our heart of hearts if this, the consummation
of Man's noblest dream, would blossom into lasting peace
or sow the dragon's teeth of some vast spatial war.

But still our task was not complete: and so at length we rose
and clad ourselves in air-tight armour—then swung aside a doorway
in the wall and issued forth upon the monstrous silence of the lunar day.

And here our imprints mingled with the footprints of the gods . . .
And now we saw, and knew—and understood.

ABSTRACTS

EDITED BY J. HUMPHRIES

The Expendable Tank Step Rocket

(K. W. Gatland, *Aeronautics*, Dec., 1948, Vol. 20, No. 1, p. 40, illus.)

Short description of a five-step atomic-powered space-ship. The tanks holding the working fluid (liquid hydrogen) are jettisoned by centrifugal force after use.

The Upper Atmosphere

(D. I. Blumenstock, *Scientific American*, Jan., 1949, Vol. 180, No. 1, pp. 30–9, illus.)

Reviews the present state of knowledge of the atmosphere and discusses some of the outstanding problems, such as the probable existence of helium at very high altitudes and the exact extent of the outer regions.

Resonance Burning in Rocket Motors

(H. Grad, *Comms. on Pure and App. Maths.*, March, 1949, Vol. 2, No. 1, pp. 79–102, illus.)

The name resonance burning has been used to describe irregularities observed in the burning of hollow powder grains, the manifestations of which are most commonly secondary pressure peaks in the combustion chamber. The paper outlines a mathematical theory which is capable of describing some of the principle features of the observed phenomena, incidentally justifying the use of the term "resonance" burning.

In the first section of the paper a brief description of the experimentally observed phenomena is given. A qualitative explanation of the phenomena

of resonance burning is presented in Section 2, followed by a more precise mathematical exposition in the next two sections in which the partial differential equations and boundary conditions satisfied by gas oscillations within the rocket combustion chamber are derived. The complex eigenvalues, on which the stability of these oscillations depend, are then computed in Section 5. The significance of the results is discussed and some suggestions as to design are made in a concluding section. The explicit solution of the initial value problem is presented in an appendix.

Other Papers Noted

Limitations of the Long-Range Missile. W. Ley. *Ordnance,* Nov.–Dec., 1948, Vol. 33, No. 171, pp 189–91, illus.

The Growth of Rocket Ordnance. F. W. F. Gleason. *Ordnance,* May–June, 1948, Vol. 32, No. 168, pp. 397–9, illus. Development from the death of Congreve in 1828 to World War II.

The Interception of Long-Range Rockets. W. Ley. *Anti-aircraft J.,* March–April, 1949, Vol. 92, No. 2, pp. 24–6, illus.

Complément à l'etude de l'évasion hors de l'attraction terrestre et de la gravitation autour de la Terre. R. Genty. *Comptes Rendus,* 31st May, 1948, Vol. 226, No. 22, pp. 1797–8, ref.

REVIEW

Physik der Weltraumfahrt

(By Otto Willi Gail. Hanns Reich, Munich, Germany, 1948. 140 pp., illus., tabs., glossary, in German. 6.50 marks.)

In this new German book on space-flight, the fundamental principles are explained in a clear and simple manner, with the aid of many diagrams. It serves as a good short introduction to astronautics, and has the advantage of containing no apparent theoretical or technical errors. Several examples of recent progress in rocketry serve to bring the book up to date, and some possibilities of the future are hazarded. W. R.

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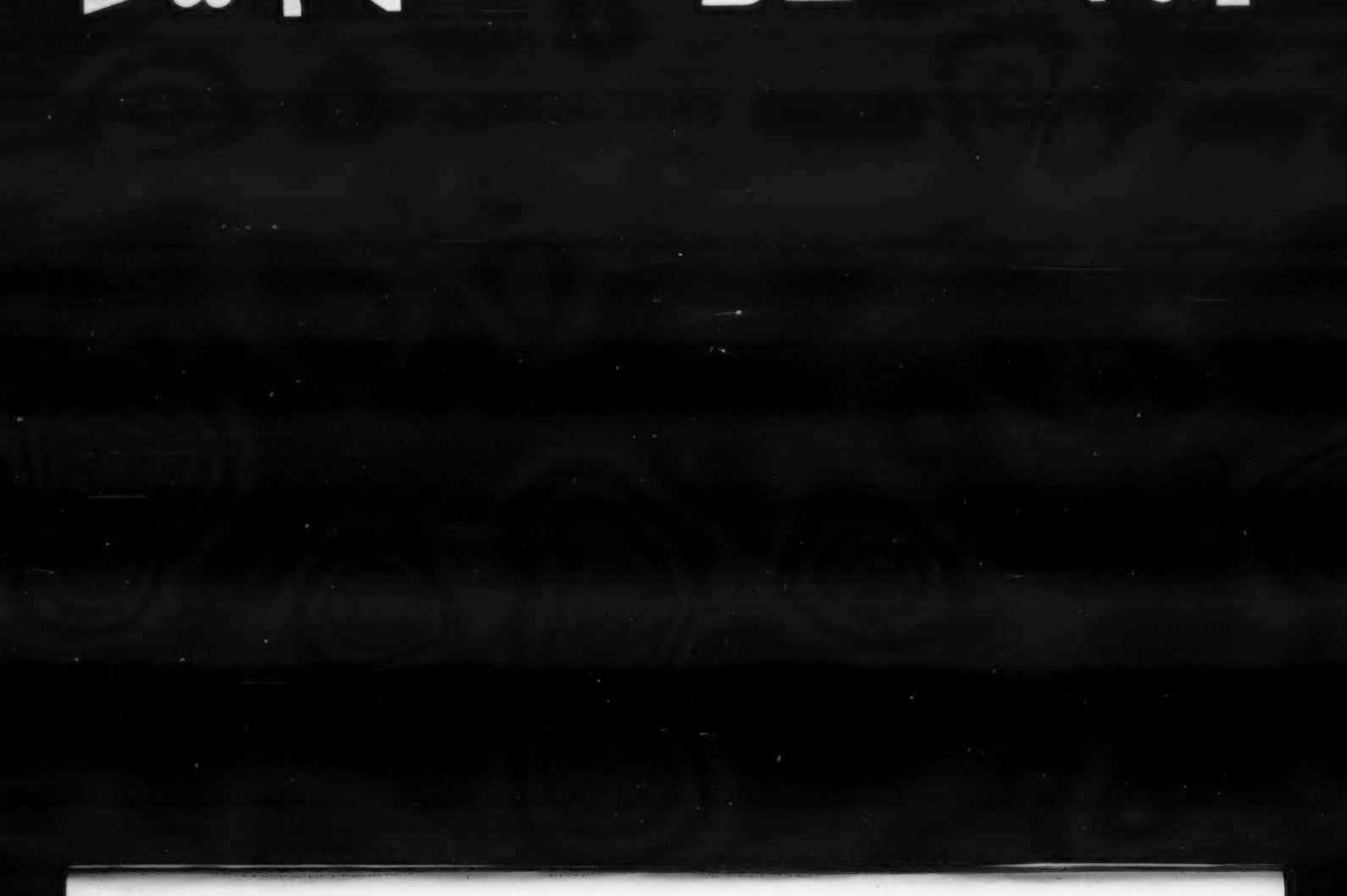
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